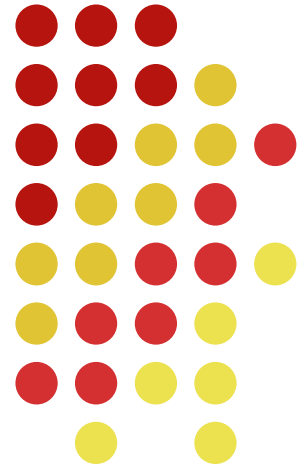
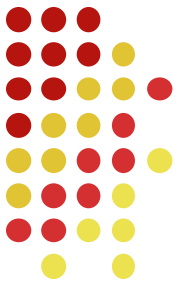


# The Interrelationship Between Speed Limits, Geometry, and Driver Behavior

Raha Hamzeie, Ph.D. Student  
Peter Savolainen, Ph.D., PE

*2016 Mid-Continent Transportation Research Symposium  
October 24<sup>th</sup>, 2016*

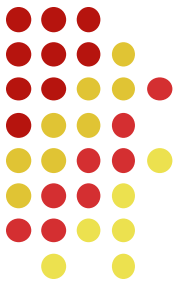
IOWA STATE  
UNIVERSITY



SHRP2



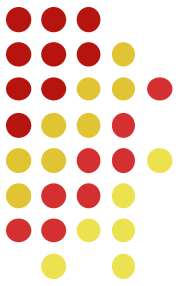
STRATEGIC HIGHWAY  
RESEARCH PROGRAM



# Overview

- Introduction
- Literature Review
  - Speed Limit & Crash Risk
  - Operating Speed & Crash Risk
- Data Description
  - Naturalistic Driving Study (NDS)
  - Roadway Information Database (RID)
  - Requested Data
- Methodology
- Results and Conclusion

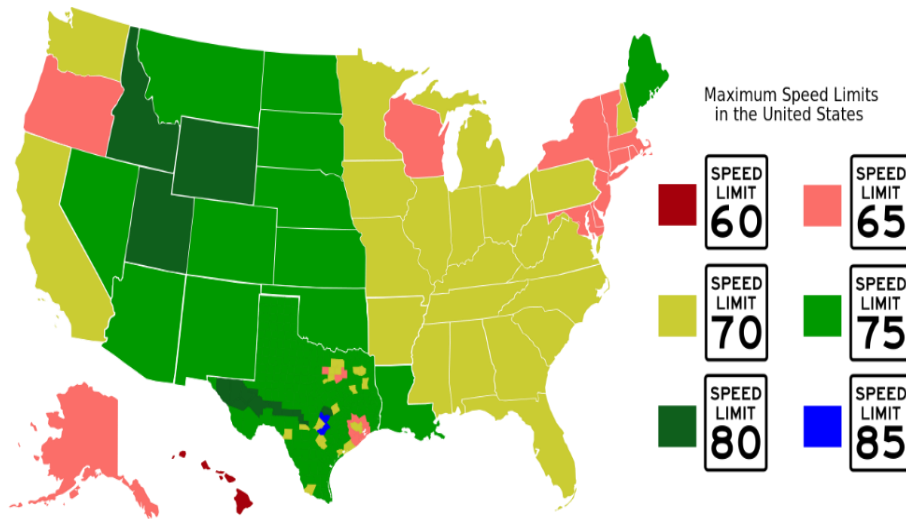
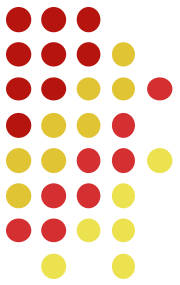
# Introduction: Recent Policy Changes



- Research has generally shown crash risk to increase as the average speed of traffic increases and as the standard deviation of travel speeds increases within a traffic stream.
- Despite these findings, numerous states have recently increased statutory speed limits to speeds as high as 85 mph.

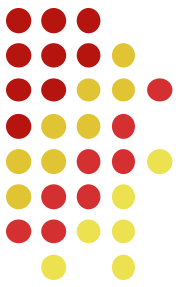
State	Type of Roadway	Prior Limit	New Limit	Year
Kansas	Rural Freeways	70	75	2011
Louisiana	Select Rural Freeways	70	75	2011
Ohio	Ohio Turnpike	65	70	2011
Arkansas	Select Rural Highway	55	60; 65	2012
Indiana	Tollway	55	70	2012
Kentucky	Select US Highway	55	65	2012
<b>Texas</b>	<b>Rural Freeways; Tollway</b>	<b>75; 80</b>	<b>80; 85</b>	<b>2012</b>
Alaska	State Highway	55	65	2013
North Carolina	Select Rural Freeways	65	70	2013
Ohio	Select Rural Freeways	65	70	2013
Utah	Select Rural Freeways	75	80	2013
Georgia	Select Interstate	55	70	2014
Idaho	Rural Freeway	75	80	2014
Illinois	Tollway; Select Freeways	55; 65	70	2014
Maine	Select Interstates	55; 65	60; 70	2014
New Hampshire	Select Interstates	65	70	2014
Pennsylvania	Rural Freeways	65	70	2014
South Carolina	Select Interstates	55	60	2014
Wyoming	Select Interstates	75	80	2014
Delaware	Select Interstates	55	65	2015
Montana	Rural Interstates	75	80	2015
South Dakota	Select Interstates	75	80	2015
Wisconsin	Rural Interstates	65	70	2015
Maryland	Select Interstates	65	70	2015
Nevada	Select Freeways	75	80	2015
Kentucky	Select Rural Highways	55	65	2015
Oregon	Select Interstates	55;65c/55t	65c/60t;70c/65t	2016
Washington	Freeways	70c/60t	75c/60t	2016 <sup>3</sup>

# Research Questions



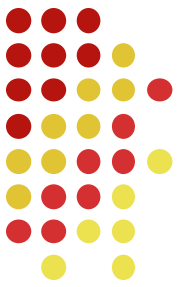
- How does driver speed selection vary among freeways with different posted speed limits?
- How do rates of crash/near-crash vary among freeways with different speed limits?

# Literature Review: Speed Limit Policies



- National Maximum Speed Limit Act – 1974 (NMSL)
- Surface Transportation Uniform Relocation Assistance Act (STURAA) – 1987
- National Highway System Designation Act – 1995

# Literature Review: Speed Limit and Crash Risk / Frequency



- Increased crash rates:

Gallaher et al., 1989 → Fatality rates increased by 2.9 per 100 million VMT  
Wagenaar et al., 1990 { 19.2% higher fatalities  
39.8% major injuries  
25.4% moderate injuries

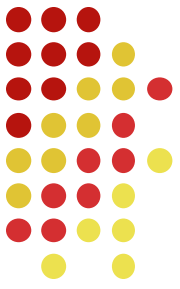
- No Safety impact:

Pant et al., 1992 { No significant difference in number of fatalities  
Slight increase in number of injury and PDO crashes

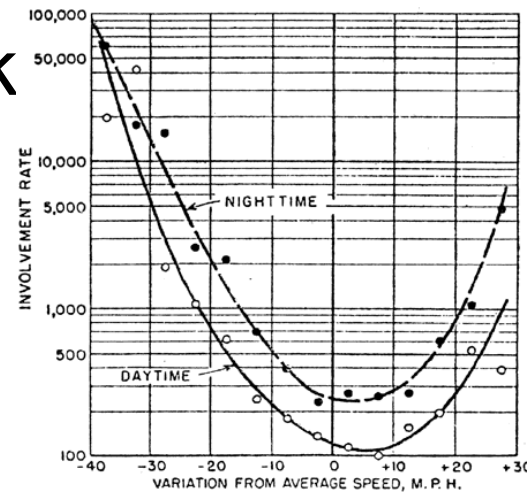
- Safety Improvements:

Lave and Elias, 1994 { Reallocation phenomenon  
3.4 – 5.1 percent reduction in state wide fatalities  
Greenstone et al., 2002 { Increase on interstates  
Reduction on urban non-interstates

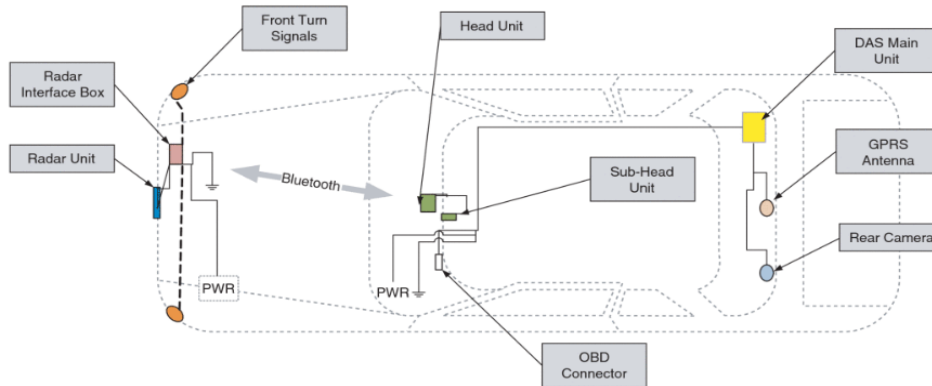
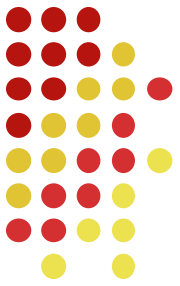
# Literature Review: Operating Speed and Crash Risk



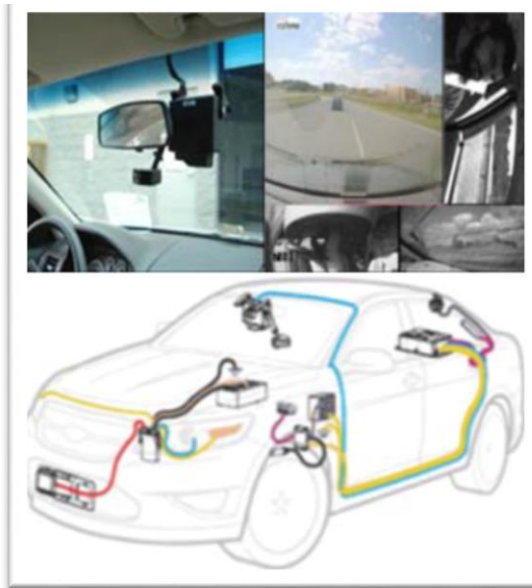
- Operating Speed and Crash Risk
  - U-shaped curve (Solomon, 1964; Cirillo, 1968; and Munden, 1967)
  - Confounding findings (White and Nelson, 1970; Evans, 2004)



# SHRP 2 Data: Naturalistic Driving Study

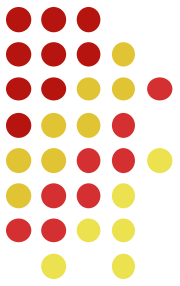


- 3092 Drivers
- 3900 vehicle drivers
- 3 years of data
- 1600 crashes
- 2900 near-crashes

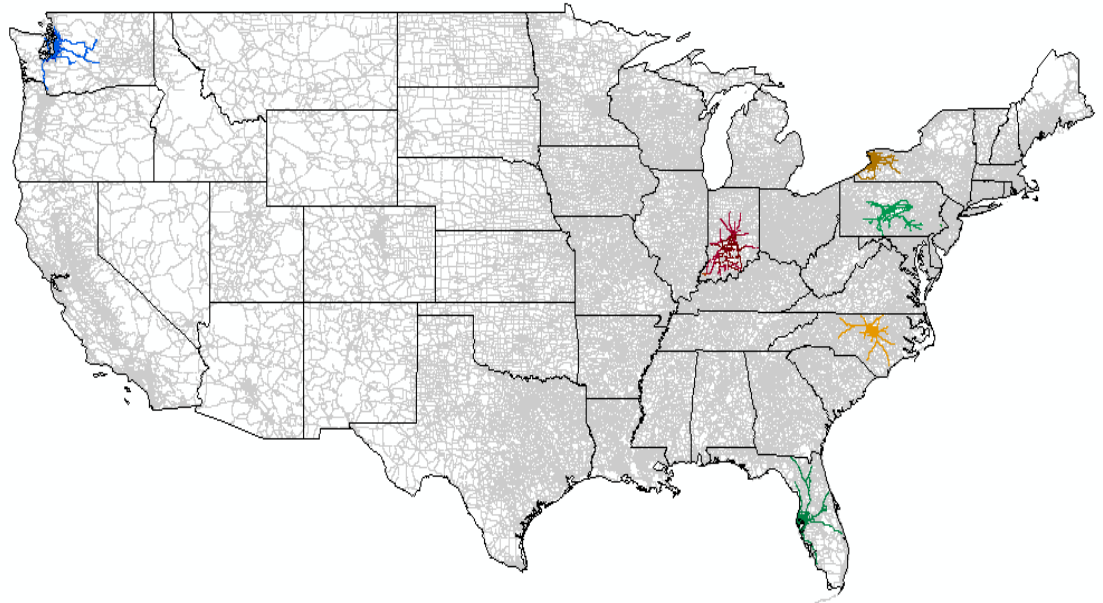




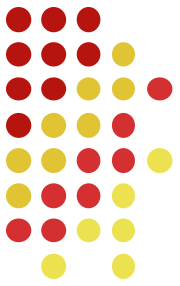
# SHRP 2 Data: Roadway Information Database (RID)



- Data Sources:
  - Existing (~200,000 miles) (DOT, ESRI)
  - Supplemental Information
  - Mobile Van Data
    - Alignment
    - Location
    - Lane
    - Shoulder
    - Rumble Strips
    - Lighting
    - Sign
    - Guardrail
    - Intersection
    - Median

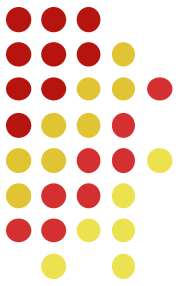


# Requested Data: InSight

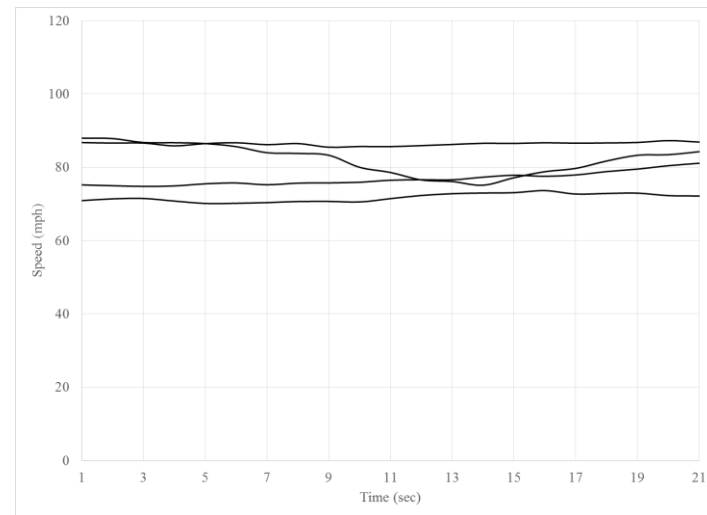


- Event Details
  - 6023 unique events
    - Event Nature
    - Incident Type
    - Driver Behavior
    - Secondary Task
    - Seatbelt Use
    - Construction Zone
    - Fault
  - Trip Summaries
    - 5925 unique trips
      - Seatbelt Use
      - ABS Activation
      - Trip Distance
      - Trip Duration
- Driver Survey
  - 2290 Unique Participants
    - Sex
    - Age
    - Education
    - Income
    - Marital Status
    - Risk Perception and Risk Taking
- Vehicle Detail Table
  - 2325 Unique Driver-Vehicle Pairs
    - Tread Depth
    - Tire Pressure
    - Factory Navigation
    - Music Control

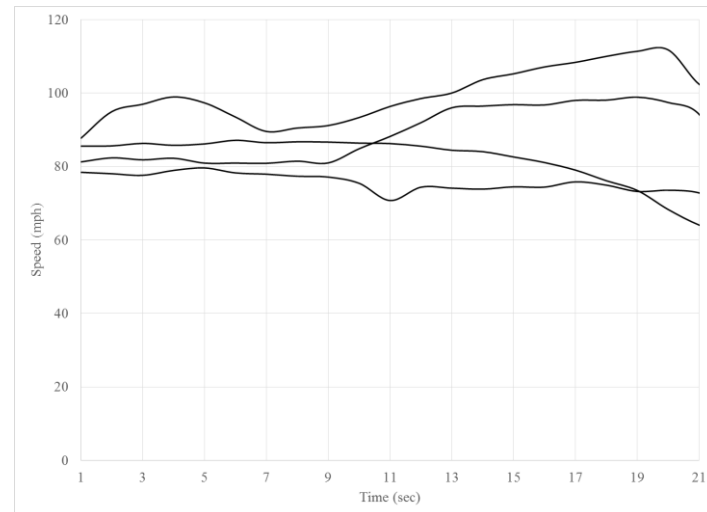
# Requested Data: InDepth (Time Series)



- Information as to the speed and location of 5683 unique events for the last 30 seconds preceding to the event outcome:
  - Speed and latitude / longitude information at every 1 second interval
  - Acceleration / deceleration information at every 0.1 second interval

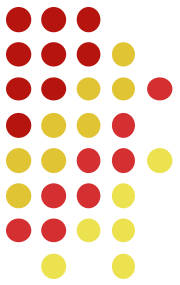


Driver 1 – Baseline Events



Driver 2 – Near-Crash Events

# Data Used: NDS Summary Statistics



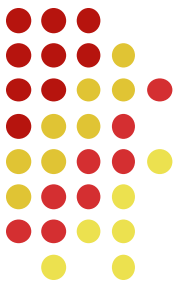
Variable	Category	Count	Variable	Category	Count
Gender	Male	3020	State	Florida	1346
	Female	2965		Indiana	291
	Unknown	38		North Carolina	985
Age	16-19	645		New York	1238
	20-24	1637		Pennsylvania	348
	25-29	705		Washington	1815
	30-34	398	Relation to Junction	Non-junction	3612
	35-39	233		Interchange/intersection	2023
	40-44	246		Entrance/exit ramp	384
	45-49	287		Other	4
	50-54	273	Alignment	Straight	4953
	55-59	277		Curve left	491
	60-64	223		Curve right	579
	65-69	308	Grade	Level	4989
	70-74	240		Grade down/dip	328
	75-79	238		Grade up/hillcrest	706
80-84	180	Lighting	Daylight	4682	
85-94	46		Dawn/Dusk	375	
Unknown	87		Dark, lighted	566	
				Dark, not lighted	500
Seatbelt Use	Proper use	5824	Weather	Clear	5417
	Improper or non-use	191		Rain/Mist/Fog	580
	Unknown	8		Snow/Sleet	26
Vehicle Type	Car	4305	Surface Condition	Dry	5176
	SUV Crossover	1225		Wet	822
	Pickup Truck	295		Snowy/Icy	25
	Van/Minivan	198	Level-of-Service	LOS A: no lead	888
Prior Crashes	0	4221		LOS A: leading traffic	2221
	1	1323		LOS B	2035
	2 or more	404		LOS C	466
	Unknown	75		LOS D	255
Prior Violations	0	3715		LOS E	132
	1	1429	LOS F	26	
	2 or more	813	Work Zone	Not work zone-related	5599
	Unknown	66		Occurred in work zone	255
				Other work zone-related	169
Event Type	Crash/Near-Crash	656	TOTAL		6023
	Baseline	5367	TOTAL		6023

# Data Used: Roadway Information Database (RID)



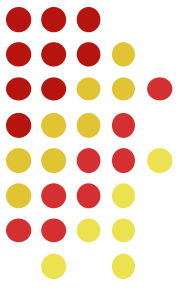
Variable	Minimum	Maximum	Mean	Std. Dev.
Lane width $\geq$ 12 ft	0	1	0.283	0.450
Lane width $\geq$ 11 ft, < 12 ft	0	1	0.478	0.500
Lane width <11 ft	0	1	0.239	0.427
Percent grade (upgrade)	0	5.7	0.591	0.959
Percent grade (downgrade)	0	5.9	0.595	0.995
Tangent segment	0	1	0.667	0.471
Curve to the left	0	1	0.170	0.376
Curve to the right	0	1	0.158	0.365
Degree of curve	0	5.9	0.473	0.854
Lighting present	0	1	0.399	0.490
55-mph speed limit	0	1	0.148	0.355
60-mph speed limit	0	1	0.375	0.484
65-mph speed limit	0	1	0.262	0.440
70-mph speed limit	0	1	0.215	0.411

1 = yes; 0 = no for binary variables



# Analysis Methods

- Regression models were estimated to examine three primary metrics of interest:
  - the average speed of vehicles during the time preceding each crash, near-crash, and baseline event;
  - the variation in travel speeds for vehicles leading up to each event as quantified by the standard deviation of speeds over this period; and
  - the rate of crash or near-crash involvement among study participants included in the sample of events.

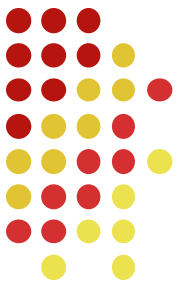


# Results:

## Regression Model for Mean Travel Speed

Variable	Total Sample			Level-of-Service A Only		
	Coeff.	Std. Err.	t-stat	Coeff.	Std. Err.	t-stat
Intercept	16.75	0.89	18.78	68.81	0.54	127.45
LOS A (no lead vehicle)	52.31	0.75	69.37	-	-	-
LOS A (lead vehicle)	53.26	0.74	72.22	-	-	-
LOS B	50.75	0.73	69.25	-	-	-
LOS C	40.20	0.75	53.85	-	-	-
LOS D	19.41	0.76	25.39	-	-	-
LOS E	11.64	0.78	14.86	-	-	-
Non-junction	1.20	0.12	10.16	0.72	0.11	6.50
Age 16 to 24	2.34	0.57	4.13	3.13	0.62	5.06
Age 25 to 59	1.70	0.58	2.93	2.43	0.64	3.79
Upgrade	-0.50	0.06	-8.81	-0.32	0.05	-6.19
Downgrade	0.63	0.06	11.26	-	-	-
Rain	-2.14	0.18	-11.69	-2.30	0.22	-10.65
Sleet or snow	-4.02	0.95	-4.24	-8.52	0.78	-10.93
Female	-0.86	0.44	-1.98	-	-	-
Work zone	-1.24	0.22	-5.59	-2.38	0.20	-11.84
55-mph limit	-7.22	0.24	-29.58	-7.53	0.23	-32.94
60-mph limit	-7.18	0.21	-34.86	-5.98	0.18	-33.58
65-mph limit	-1.61	0.24	-6.78	-2.62	0.19	-13.85
Degree of curve	-0.33	0.05	-6.14	-0.10	0.05	-2.06

- For LOS A, speed increased with increasing limit
  - 1.5 – 3.5 mph increase in speed per 5 mph increase in speed limit
- Highest speeds for males and youngest age groups



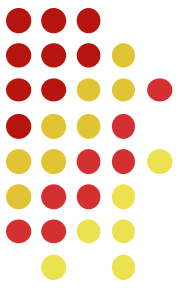
# Results:

## Regression Model for Speed Std. Deviation

Model Term	Coeff.	Std.Err.	t-stat
Intercept	2.41	0.55	4.35
Non-junction	-0.36	0.08	-4.45
LOS A (no lead vehicle)	-1.36	0.56	-2.42
LOS A (lead vehicle)	-1.19	0.56	-2.14
LOS D	1.19	0.58	2.04
LOS E	1.42	0.61	2.35
Work Zone	0.82	0.18	4.60
Work Zone approach	0.63	0.23	2.71
55-mph limit	0.40	0.12	3.43
60-mph limit	0.30	0.09	3.45

- Speeds variability is largely affected by traffic congestion
- Speeds were highly variable approaching or within work zones
- Speeds were less variable at higher speed limits



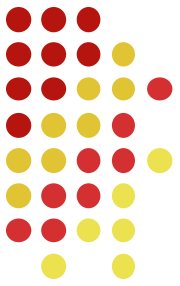


# Results:

## Logistic Regression Model for Crash/Near-Crash Risk

Model Term	Coeff.	Std.Err.	t-statistic	Odds Ratio
Intercept	-2.54	0.42	-5.99	N/A
Non-junction	-0.29	0.17	-1.77	0.75
Vertical curve	0.42	0.21	2.03	1.52
Age 35 to 74	-0.87	0.20	-4.39	0.42
LOS A	-2.22	0.26	-8.46	0.11
LOS B	-1.17	0.22	-5.21	0.31
LOS D	0.62	0.32	1.97	1.86
Mean Speed	0.02	0.01	3.25	1.02
Speed Std. Dev.	0.35	0.04	8.09	1.42

- Odds of crash/near-crash increased by:
  - 2% for every 1-mph increase in travel speed
  - 42% for every 1-mph increase in std dev.
  - 52% where vertical curvature is present
  - 86% during LOS D (vs. LOS C/E/F)
- Odds of crash/near-crash were lowest for:
  - Drivers age 35-74
  - Non-junction areas
  - LOS A and B



# Conclusion:

- Speed:
  - Increase:
    - Posted speed limit
    - Younger drivers
    - Male drivers
    - Downgrades
  - Decrease:
    - Horizontal curves
    - Upgrades
    - Adverse weather condition
    - Work zone
- Crash Risk:
  - Average speed
  - Speed standard deviation
  - Congestion
  - Vertical curves
  - Younger drivers



# Thank you!

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